Since the process $Gp(Z)$ has no time lag or zeroes (with the simplifying assumptions), then $M(Z)$, the system transfer function, is optimized for a step input by setting $M(Z) = Z^{-1}$ (Ref. 1).

Solving for $D(Z)$ in Eq. (1) yields

$$D(Z) = \frac{M(Z)}{1 - M(Z)} \times \frac{1}{Gp(Z)}$$

and substituting values yields

$$D(Z) = \frac{Z^{-1}}{1 - Z^{-1}} \times \frac{Z - 1}{K_1}$$

$$= \text{constant} \left(\frac{1}{K_1}\right)$$

where $K_1 = 0.0016$. If $D(Z)$ is selected for this value, then the output response is

$$C(Z) = \frac{1}{Z - 1} = Z^{-1} + Z^{-2} + Z^{-3} \cdots$$

The equation for $C(Z)$ implies that the system output will respond to the step input with a delay of one period of the sampling rate.

However, the ± 1 count in the counter does effect the loop; therefore, a variable dampening factor is utilized in the system. The factor $\tau = 1$ when driving the system toward a desired frequency position. The factor $\tau = 0.1$ is then selected by the program when rate and frequency position have been achieved. The value for $\tau = 0.1$ was selected by a system simulation on the SDS 920 and has the effect that $C(Z)$ does not reach zero steady-state for a step input until a delay of 7 sample periods.

The desired S-band frequency rates can be achieved from approximately 2 to 400 Hz/s.

Mode II. The wave analyzer (HP-302 or HP-310A) noise level and the S-band carrier are measured by the computer program and stored as constants. The frequency relationships to these data points and to the data points of the swept spectrum are obtained from the counters.

The voltage signal from the wave analyzer represents the signal power within the selected noise bandwidth of the analyzer. The sampled output of a particular spectrum interval (i.e., 5 Hz, if a 5-Hz/s rate is selected) is summed, squared, and expressed in volts. Then a comparison is made with the previously measured carrier power to form a relative level expressed in dB.

A machine language subroutine (SDS-920 symbolic) is required to speed the operation of handling the sampled data. The sample rate is a constant 333 samples/s. A 1-ms pulse from the station timing system is used to initiate the sample interrupt.

The graphic display of the RF spectrum allows real-time observation, as well as a permanent record of power and frequency measurements. Any portions of the spectrum may be further examined by plotting an expanded section (i.e., sweeping the spectrum at a slow rate) of the area in question. Results have shown that at power levels of -40 dB below the carrier, relative accuracies of ± 1 dB are obtained. An example of the output is illustrated in Fig. 4.

d. Development. To reduce the time involved in analyzing the spectrum, it is proposed to use the fast discrete Fourier transform (DFT) to examine the S-band spectrum. Preliminary testing has been successful in utilizing the Welch (SPS 37-40, Vol. III, pp. 6–8) version of the DFT to examine the spectrum from the carrier to approximately 160 kHz. The data obtained are comparable to the analog technique presently used. The time involved in a spectrum observation is reduced by a factor of 10 to 20.

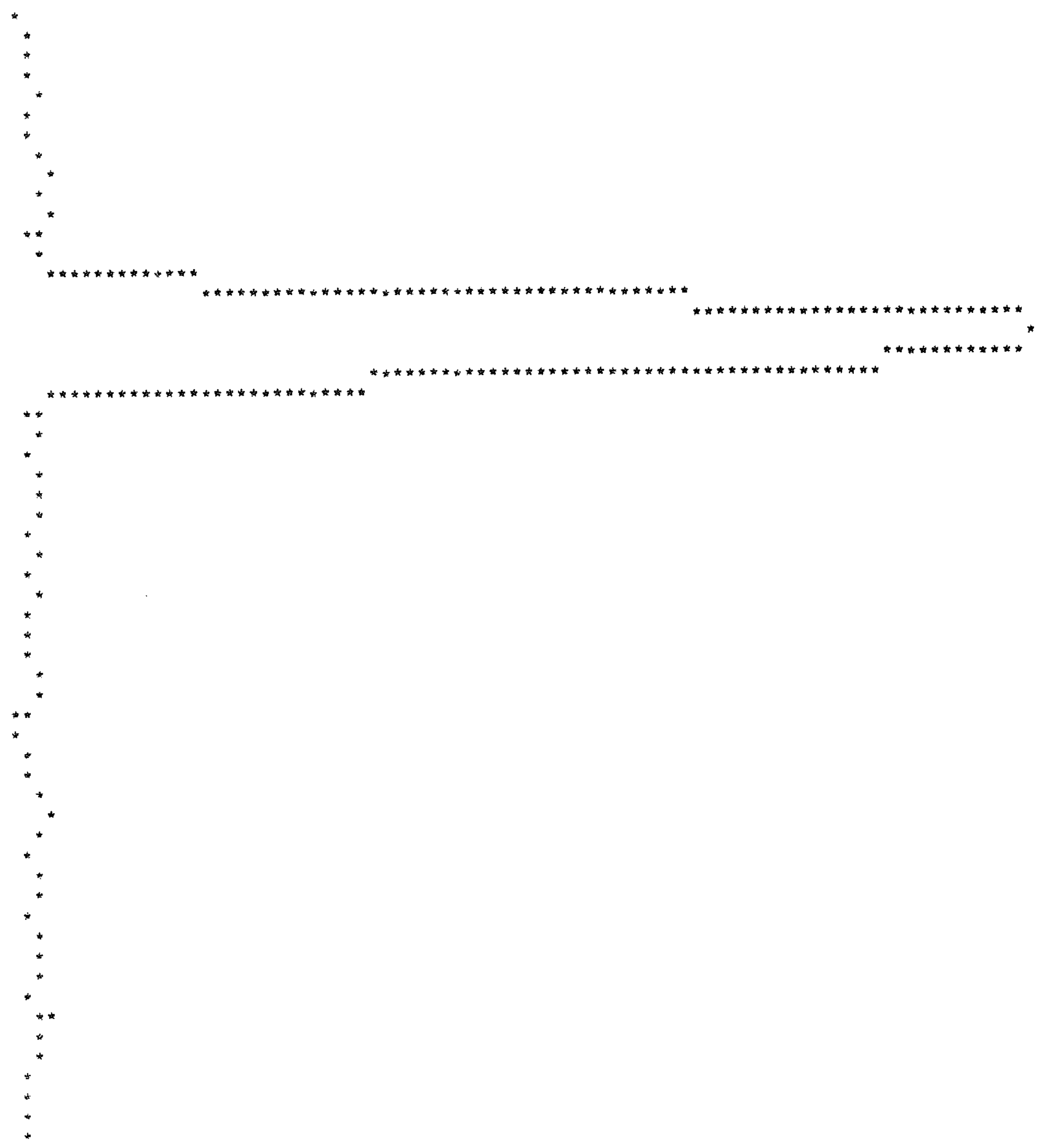
Reference

1. Kuo, D. C., *Analysis and Synthesis of Sampled-Data Control Systems*. Prentice-Hall, Inc., Englewood Cliffs, N. J., 1963.

C. Facility Engineering

1. SFOF Emergency Power Subsystem, *R. V. Phillips*

a. Introduction. The SFOF emergency power subsystem discussed in SPS 37-50, Vol. II, pp. 189–191, SPS 37-51, Vol. II, pp. 170–171, and SPS 37-57, Vol. II, pp. 170–173, is incrementally becoming a reality. The uninterruptable power system (UPS) began on-line operation on May 3, 1969, and the engine-driven standby power plant is scheduled for completion in early 1970. The installation of the central supervisory monitor and control system is in process and will be operable with completion of the standby power plant.



-001.528	-043.31
-001.528	-042.74
-001.414	-042.59
-001.300	-042.72
-001.188	-042.48
-001.074	-042.91
-000.959	-042.77
-000.846	-042.25
-000.546	-041.88
-000.732	-042.42
-000.617	-041.99
-000.504	-042.75
-000.390	-042.03
-000.276	-035.53
-000.162	-015.03
-000.162	-001.43
-000.048	-000.69
+000.066	-006.55
+000.180	-026.10
+000.293	-041.72
+000.408	-042.98
+000.408	-042.07
+000.521	-042.53
+000.634	-042.15
+000.749	-042.32
+000.861	-042.35
+000.975	-042.84
+001.088	-042.49
+001.088	-042.99
+001.202	-042.41
+001.316	-042.86
+001.429	-042.55
+001.541	-042.56
+001.654	-042.44
+001.768	-042.49
+001.768	-043.09
+001.881	-043.01
+001.995	-042.69
+002.109	-042.85
+002.222	-042.47
+002.337	-041.96
+002.451	-042.07
+002.451	-042.76
+002.564	-042.36
+002.678	-042.32
+002.792	-042.96
+002.906	-042.14
+003.020	-042.42
+003.133	-042.36
+003.133	-042.74
+003.246	-041.99
+003.361	-042.03
+003.475	-042.11
+003.589	-042.76
+003.703	-042.73
+003.703	-042.66
+003.703	-042.78
+003.930	-042.61

Fig. 4. Portion of *Apollo 11* frequency spectrum (DIS spectrum plot; 2287.5-MHz carrier; rate = 100 Hz/s)

b. Uninterruptable power system. The dependable on-line operation of the UPS before and during the *Mariner* Mars 1969 encounter period attests to the significant advancement made towards providing "computer reliable" power to the SFOF. The installation of the UPS was completed at the SFOF in April 1969. During extensive acceptance tests made in April and May, the UPS exceeded all requirements outlined in the bid specifications.

The UPS is composed of rectifiers, inverters, and batteries. The utility power is connected through the UPS to the critical loads to maintain constant and disturbance free power. Four 480-V, 3-phase, 60-Hz rectifier units produce 405 Vdc and are connected to a 2,000-A bus. Current from the bus feeds through four dc-to-ac inverter units to the critical load. An impedance inserter is installed on the output of each inverter to clear the circuit in case of a fault in the inverter. Two banks of batteries are connected to the 2,000-A bus parallel with the rectifier output. One battery bank consists of 184 Gould FT 15 cells with 804-A capacity on an 8-h basis. The other bank consists of 184 C&D LCU 27 cells with 1940-A capacity at an 8-h rate.

To determine the UPS acceptability with respect to the specifications and manufacturer design parameters,

Table 1. UPS test results: input requirements

Parameter	Specifications	Test results
Harmonic	15% current distortion	5% circuit $1B_3$, carrying 520 A
Voltage	460 V, 3-phase, 4W ±10%	System performed satisfactorily when varied from 420 to 508 V
Frequency	57–63 Hz	System performed satisfactorily when varied from 56 to 63 Hz
Current in-rush	25 to 100% of full-rated load over 15 s	In-rush on 2 rectifiers = 300 A; full load on 2 rectifiers = 1208 A; UPS returns to rated load in 15 s
Total system efficiency	80% with supply at 0.8 pF; load at 0.8 pF lagging	91% at 750 kV-A, 08-pF load; 67% at 200 kV-A, 09-pF load

Table 2. UPS test results: output (steady-state)

Parameter	Specifications	Test results
Voltage (steady-state)	120/208 Vac ±2%, 3-phase, 4 wire, adjustable ±5%	With stepped load increases 0–150–300–468–480 kW, voltage changed from 215 to 212 V; negligible under steady-state; adjusts to 190-224 V
Frequency	Continuously adjustable 57–63 Hz ±0.5% stability; when operating free-running, oscillator shall hold inverter output frequency to ±0.5% for both steady-state and transient conditions; total frequency deviation, including short-time fluctuations and drift, shall not exceed ±0.5% from rated frequency during 24-h period	±1/10 Hz or 0.16%
Harmonic content	Maximum 5% rms	2.09% at 750 kV-A, 0.8-pF load
	Maximum 3% single harmonic	1.55% at 750 kV-A, 0.8-pF load
Unbalanced load	Inverter output voltage shall not differ between phases by more than 3% or line-to-neutral voltage by more than 5% with unbalanced phase to neutral kV-A loads of 15%; frequency stability shall not be adversely affected under this condition	Phase to phase, 2%; phase to N, 2.8%; loads per phases A,B,C, respectively: 250, 250, 287 kV-A
Phase displacement	Phase displacement of inverter output voltage shall be maintained at 120 ±5 electrical deg with unbalanced phase to neutral kV-A loads of 15%	2 deg with unbalance, as noted above

simulated and real tests were performed during installation and initial operation. The results of the tests are delineated in Tables 1–3.

Several voltage dips from commercially supplied power have been recorded. Table 4 lists these occurrences and the effects.

The UPS meets or exceeds all specifications, as shown by the documented tests, performance during malfunctions, and voltage dips. The stability and accuracy of this trouble-free power system will reduce the number of critical power failures and provide confident mission support.

c. Standby power. The standby power plant is in the process of completion. The engine-generators are in place. The power control center has been delivered. Installation of ancillary items and connections to the major equipment are now in process. The basic major construction is scheduled for completion in January 1970.

d. Central supervisory monitor and control system. Installation of the central supervisory and monitoring system is complete except for the connections of alarm points in the standby power plant. Completion of the basic unit is scheduled for December 1969.

Table 3. UPS test results: output (transient)

Transient cause	Maximum deviation at rated voltage, ±%[a]	Test results
187.5-kV-A load steps to 750-kV-A total load	8	Maximum 5.3%
Loss of ac input power or excursions of input power in excess of system tolerances (750-kV-A load)	5	Negligible
Return of ac input power (750-kV-A load)	5	Negligible
Dropping one power converter off output power line by switching (750-kV-A load)	8	Maximum 3%
Bringing one power converter onto output power line by switching (750-kV-A load)	8	Maximum 3%
Dropping one power converter off output power line as a result of an internal fault, e.g., silicon-controlled rectifier or diode short (500-kV-A load)	8	Maximum 4.5%

[a]The UPS shall regulate voltage transients for the output load changes and switching actions to the limits indicated when all four modules are on the line.

Table 4. Votage transients induced by commercial power

Voltage dip, V	Time	Cause	Remarks
30-40 (dips and spikes)	5-11-69 (all day)	Weather conditions	No equipment loss or adverse effects noted as had previously been reported under similar conditions
130	5-14-69 (08:21)	Boom of construction crane touched 66-kV transmission line, reflecting transient into commercial power	Systems on UPS power not affected
80	5-14-69 (10:40)	Transient from MacNeil Substation	Systems on UPS power not affected

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